Lipids and Fatty Acids of Three Species of Northeast Pacific Finfish Harvested in Summer*

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Abstract:

The purpose of this study was to measure the total lipid and cholesterol content and fatty acid profile of chinook salmon (*Oncorhynchus tshawytscha*), Dover sole (*Microstomus pacificus*), and sablefish (*Anoplopoma fimbria*). All three species of fish were caught off the coast of Oregon in late summer, 1987. Salmon contained 6.95% total lipid, Dover sole contained 1.03%, and sablefish contained 5.72%. For the fatter fish these values were considerably lower than the average values found in literature. The two fatter fish contained approximately 1 g n-3 fatty acids per 100 g wet weight, again lower than the average values found in literature. This study demonstrates the need to increase the information available about seasonal variation in lipid content of Finfish so that accurate dietary recommendations can he made.

Article:

INTRODUCTION

Since epidemiological studies among Eskimos and Japanese fishermen and farmers (Bang and Dyerburg, 1980; Kagawa et al., 1982) first suggested that the consumption of fish might lower the risk of cardiovascular disease (CVD), considerable interest has been generated in their n-3 fatty acid content. These highly unsaturated fatty acids are thought to have hypolipemic, antithrombotic effects (Goodnight, 1988; Connor, 1988).

In early studies to assess the therapeutic value of fish, often large doses (>15 g/d) of n-3 fatty acids supplied as the :fish oil were used (Harris and Connor, 1980; Phillipson et al. 1985). Because it is the consumption of fish. and not the use of fish oils that has been linked to decreased incidence of CVD and because such high doses are impractical and may be associated with intolerable gastrointestinal side effects and poor compliance (Radack et 1990), dietary fish may provide a more attractive source of n-3 fatty acids. However, since the effects of n-3 fatty acids are known to be dose dependent (Harris et al, 1990; Sanders and Roshana, 1983), accurate dietary recommendations require the content of n-3 fatty acids in fish be known.

Although the amount of reference information about the lipid and n-3 fatty acid content of fish is becoming more extensive (Sidwell, 1981; Exler 1987; Krzynowek and Murphy, 1987; Gooch et al_ 1987; Krzy.nowek et al., 1989), there is still an inadequate data base on the nutritional composition of seafood. The proximate corn-- position, especially the lipid content, between and within species of fish is highly variable (Stansby, 1976). There are numerous factors which

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,contribute to this variability: food available to the fish, location of catch. the size of the fish, their stage of maturity, individual variability, and location on the fish from which the sample is taken (Hardy and King, 1989). The n-3 content can also vary but the variation in total lipid content is more dramatic than that of the n-3 fatty acid content: the former can be a 13-fold variation while the latter may he only a 2-fold variation (Stansby, 1986). Differences in the lipid and n-3 fatty acid content may have important consequences in menu planning.

Limited information is available about the variability of lipid and fatty acids content of fish important to the fisheries industry of the Northeast Pacific. The purpose of the study was to measure the level of total cholesterol, and the fatty acid profile in Dover sole (*Microstomus pacificus),* chinook salmon (*Oncorhynchus tshawytscha*), and sablefish (alias black cod; *Afloplopoma fimbria*) harvested from the Northeast Pacific under clearly defined conditions.

MATERIALS AND METHODS

All of the fish were caught off the Oregon coast on September 9-10, 1987. They were immediately eviscerated, mechanically skinned and &boned, and minced, and a single composite was made of each species of fish. The composite sample, separated into subsamples of about 1 kg each, were vacuum-packed and blast frozen. These preparations were made at the Oregon State University Seafood Laboratory in Astoria, Oregon. This technique of preparing the fish removes all the edible flesh. They were, maintained at -40°C until used. A sufficient number of fish were obtained for each species to provide about 136 kg (300 pounds) of minced flesh_ This would represent about 25 salmon, 130 sablefish, and 450 Dover sole. This method of preparing a composite sample assures us that the selection of any aliquot provides a representative, homogeneous sample of tissue.

Lipids were extracted from six aliquots of each of these samples using chloroform and methanol (l:2, v/v) according to the method of :Ugh and Dyer (1959). An aliquot of each extract was used for the gravimetric determination of total lipids (AOAC Method 7.061, 1984) and the fatty acid profile. The recovery of trialyceride added to a sample of fish was greater than 95%.

The fatty acid methyl esters were identified by gas liquid chromatography (Song and ,Wander, 1991) using a Hewlett-Packard 5890 gas chromatograph (GC) (Avondale, PA). The GC was equipped with a 30 X 0.25 mm i.d., 0.25-pm film thickness SP 2330 column (Supelco, Inc.,Bellefonte, PA). Helium was the carrier gas and was used at a flow rate of 1 ml/min with a split ratio of 1.00:1. Hydrogen and air flow rates were 30 ml/min and 300 ml/min, respectively. Both the injector and the detector were maintained at 235°C. The column was programmed for 4 mini at 170°C and then for 3°C per minute rise up to a maximum of 225°C. The GC interfaced with a Hewlett- Packard 18550A microprocessor which reported retention time, peak area, and area percent for each component. These data were transferred directly to a microcomputer via a commercial communications program (MasterLink, Infrotronix, Seattle, WA). Fatty acid methyl esters were identified by comparing to authentic standard mixtures (Sigma., St. Louis, MO; NuChek Prep, Inc., Elysian, MN; Supleco, inc.., Bellefonte, PA) and quantitated using 23:0 as the internal standard. The cholesterol content of the fish was measured with a colorimetric method using ferric chloride (Sweeney and Weihrauch, 1976). Recovery of cholesterol added to a sample was 91.2%. All analyses were performed on raw tissue and data are given on a wet weight basis.

RESULTS AND DISCUSSION

The total lipid and cholesterol content of the chinook salmon, Dover sole, and sablefish. are given in Table 1. As mentioned earlier, the lipid content of fish is highly variable. By obtaining a composite sample of minced flesh from several fish caught at the same site and the same time for each of the species studied, much of the source of this variation is eliminated.

Our value of 1.03% total lipid for Dover sole is similar to the value 010.95% (range' 0.39-3,32%) reported by Stansby (1976) and 0.9% (range 0.6-1.2%) reported by Sidwell (1981). Exler (1987) does not report this species separately but gives a collective value for flatfish (genus, *Bothidae* and *Pleuronectidae)* of 1.19%. None of the fish included in this study are reported by Gooch *et al.* (1987) because their data are confined to southeastern finish species nor by Krzynowek *et al.* (1989) because their data are confined to finfish of the Northwest Atlantic. The agreement in the fat. content between. different studies is typical for low fat fish. As a class, flattish have a composition similar to that of most bottom-feeding fish in which the total lipid content is relatively low. Because such fish do not usually migrate over wide areas, fat is not stored in their muscular tissue for future requirements. Hence, large variations in the total lipid. content are not found (Stansby, 1976).

Our value of 6.95% total lipid for chinook salmon is lower than the average value of 10.44% reported by Extler (1987), 11.6% by &dwell ()981), 11.5% by Stansby (1976),, and 13.2% by Gruger et al. (1964). However, two of these sources give a range of fat for chinook salmon: Sidwell (1981) gives a range of 2.2-19.0%; Stansby (1976), 7.2- 11.5%. Although our value is within these ranges, overall the fish we analyzed appear to have a lower fat content than is generally thought to be present in ch i nook salmon. Salmonids tend to have their highest fat content just before they embark on their migration up rivers to spawn. Consequently, fish caught by net fishing in fishing areas, at the mouths of rivers generally have higher lipid levels than fish from populations that are caught offshore by trollers before upstream migration begins (Hardy and King, 1989). Since our fish were caught offshore, their low fat content reflect these facts.

Similarly, the value of 5.72% total lipid that we obtained for sablefish is lower than the 15.30% reported by Exler (1987), the 15.296 reported by Sidwell (1981), and the

TABLE 1

TOTAL LIPID AND CHOLESTEROL CONTENT OF CHINOOK SALMON, DOVER SOLE, AND SABLEFISH[a]

	Total lipid (g/100g[b])	Cholesterol (mg/100g)
Salmon	7.0±0.58 (n=6)	90±17.0 (n=6)
Dover sole	1.0±0.11 (n=7)	68±2.8 (n=6)
Sablefish	5.7±0.41 (n=6)	69±2.2 (n=6)

[a] Mean ± SD.
[b] Wet weight.

TABLE 2

FATTY ACID COMPOSITION (RELATIVE WEIGHT % AND g/100 g) OF CHINOOK SALMON[a]

	Wt. %	g/100g[b]
14:0	5.2±0.23	0.29±0.03
16:0	21.0±0.26	1.20±0.09
18:0	4.7±0.13	0.27±0.02
20:0	0.18±0.08	0.01±0.00
24:0	0.03±0.06	ND
TOTAL SFA	31.0±0.55	1.8±0.14
16:1(n-7)	8.5±0.26	0.49±0.04
18:1(n-9)t	0.14±0.07	0.01±0.00
18:1(n-9)c	23.7±0.40	1.35±0.01
18:1(n-7)	6.2±0.33	0.35±0.02
20:1(n-9)	1.9±0.82	0.11±0.05
22:1	ND	ND
24:1	0.7±0.29	0.04±0.02
TOTAL MUFA	41.0±0.43	2.3±0.17
18:2(n-6)	1.0±0.27	0.05±0.01
18:3(n-3)	0.7±0.39	0.04±0.02
18:4(n-3)	ND	ND
20:3(n-6)	0.16±0.07	0.01±0.00
20:4(n-6)	5.76±0.09	0.33±0.03
20:5(n-3)	7.8±0.18	0.44±0.03
22:5(n-3)	3.0±0.72	0.17±0.05
22:6(n-3)	9.6±0.14	0.55±0.05
TOTAL PUFA	28.0±0.88	1.6±0.14
TOTAL (n-6)	6.9±0.27	0.39±0.02
TOTAL (n-3)	21.0±0.97	1.2±0.13

[a] Mean ± SD; $n = 6$; ND = not detected, levels below 0.01% or 0.005 g/100 g.
[b] Wet weight.

15.1% reported by Stansby (1976). However, Onager el at (1964) reported a total lipid content for one sablefish caught in December 1959 of 6..4% and Stansby gives a range of 2.76-22.9% (1976). Fatter fish, such as herring, mackerel, and sablefish, store excess fat in their muscle, mostly as triglycerides. Seasonal changes in food habits arc reflected in changes to the fat content of their bodies. Herring had a fat content of 5% when caught in January, a time when food is scarce, but 12% in July when food tends to be plentiful (Krzynowek al., 1989). However, limited information is available about seasonal variation in the fat content of sablefish.

These variations in fat content have important consequences for menu planning. For instance, a day's menu containing 2000 kcal. might provide a 100-g serving (about :31 ounces) of sablefish. Using the value found in literature (Exler, 1987) for the fat content of sablefish, this menu would provide 37% of its caloric value as fat, However, if the only change made to the menu were to use sablefish similar to that analyzed in our study, the diet would provide only 32% kcal as fat. The diet, instead of being a high fat diet, would be moderate in fat.

The cholesterol content of the three species of fish is also given in Table 1. Limited information is available about the variations in the cholesterol content of fish but, in general, our values are higher than others reported. Where we found 91, 68, and 69 mg/100 g wet weight for chinook. salmon, Dover sole, and sablefish, respectively, Exler (1987) reports 80, 58. 49 mg/100 g. Sidwell (1981) does not give values for these species. Krzynowek et al. (1989), based on their experience with the analyses of many

TABLE 3

FATTY ACID COMPOSITION (RELATIVE WEIGHT % AND g/100 g) OF DOVER SOLE[a]

	Wt. %	g/100g[b]
14:0	4.9±0.34	0.02±0.00
16:0	20.4±0.39	0.10±0.01
18:0	6.5±0.22	0.03±0.00
20:0	0.05±0.09	ND
24:0	ND	ND
TOTAL SFA	31.9±0.52	0.16±0.01
16:1(n-7)	4.5±0.23	0.02±0.00
18:1(n-9)t	0.59±0.06	ND
18:1(n-9)c	7.8±0.15	0.04±0.00
18:1(n-7)	4.4±0.18	0.02±0.00
20:1(n-9)	1.43±0.04	0.01±0.00
22:1	ND	ND
24:1	2.3±1.54	0.01±0.01
TOTAL MUFA	21.1±1.53	0.11±0.01
18:2(n-6)	0.60±0.04	ND
18:3(n-3)	0.5±0.53	ND
18:4(n-3)	ND	ND
20:3(n-6)	0.22±0.01	ND
20:4(n-6)	5.5±0.20	0.03±0.00
20:5(n-3)	16.9±0.36	0.08±0.01
22:5(n-3)	5.5±0.37	0.03±0.00
22:6(n-3)	17.8±0.51	0.09±0.00
TOTAL PUFA	47.0±1.13	0.23±0.01
TOTAL (n-6)	6.3±0.19	0.03±0.00
TOTAL (n-3)	40.7±1.22	0.20±0.01

[a] Mean ± SD; $n = 4$; ND = not detected, levels below 0.01% or 0.005 g/100 g.

[b] Wet weight.

species of finfish over many years, recently conjectured ±20% of the mean for all the cholesterol values reported in the literature would give quite reliable dietary amounts for any given species. They do note, however, that this rule is invalid for mackerel which has a wide range of reported cholesterol values. If the data given in Exler (1987) are considered means, our cholesterol levels fail outside the predicted range. Greater sampling is required, however, before it can be established that the species of fish. used in this study are characterized by larger variations in cholesterol content than are associated with most species of finfish.

The fatty acid content of the chinook salmon, Dover sole. and sable:fish is given in Tables 2, 3, and 4, respectively. The values are reported both as percentage of total fatty acid methyl esters and as g1100 g of raw, wet weight of sample. As expected the: fatty acids present in greatest amount for the two fatter fish, ,chinook salmon and sablefish, are 16:0 and 18:1 (n-9)c. Although Exler (1987) also reports these as the most abundant fatty acids, he shows amounts higher than those present in the fish we: analyzed. Consumption of 100 g of salmon by our data would provide 1.77 and 2.34 g saturated (SFA) and monounsaturated (MUFA) fatty acids, respectively; sablefish, 1.34 and 1.83 g. Exler (1987) reports that salmon would provide 2.51 g SFA and 4.48 g MUFA and sablefish 3.20 and 8.16 g. Ackman (1990) also reported that :sablefish was high in

SFA and MUFA. The lower content of these two groups of fatty acids in the fish analyzed in our study parallels their lower fat content.

For human dietary purposes these differences might be consequential. The removal of SFA from a diet is more effective in lowering serum cholesterol than the addition

TABLE 4

FATTY ACID COMPOSITION (RELATIVE WEIGHT % AND g/100 g) OF SABLEFISH[a]

	Wt. %	g/100g[b]
14:0	5.5±0.16	0.23±0.02
16:0	21.8±0.43	0.93±0.09
18:0	3.80±0.06	0.16±0.02
20:0	0.25±0.01	0.01±0.00
24:0	ND	ND
TOTAL SFA	31.4±0.64	1.3±0.13
16:1(n-7)	9.4±0.74	0.40±0.06
18:1(n-9)t	0.22±0.03	0.01±0.00
18:1(n-9)c	22.9±0.34	1.0±0.10
18:1(n-7)	8.7±0.40	0.37±0.05
20:1(n-9)	0.97±0.07	0.04±0.01
22:1	ND	ND
24:1	0.7±0.12	0.03±0.01
TOTAL MUFA	43.0±0.60	1.8±0.21
18:2(n-6)	1.39±0.08	0.06±0.01
18:3(n-3)	0.85±0.01	0.04±0.00
18:4(n-3)	ND	ND
20:3(n-6)	0.16±0.01	0.01±0.00
20:4(n-6)	3.9±0.11	0.17±0.02
20:5(n-3)	8.3±0.45	0.35±0.05
22:5(n-3)	1.2±0.36	0.05±0.01
22:6(n-3)	9.8±0.46	0.42±0.06
TOTAL PUFA	25.7±0.58	1.1±0.14
TOTAL (n-6)	5.5±0.14	0.23±0.02
TOTAL (n-3)	20.1±0.67	0.9±0.12

a Mean ± SD; a = 6; ND = not detected, levels below 0.01% or 0.005 g,/100
b Wet weight.

of polyunsaturated fatty acids to it (Keys, 1984). Additionally, MUFA have been shown to limit the decrease in high density lipoprotein cholesterol concentration that accompanies increased PUFA. consumption (Mattson and Grundy, 1985) and may modulate eicosanoid synthesis so as to decrease thrombogenie potential (Kinsella, 1990). Because of these potential physiological consequences of dietary fatty acids, knowing their intake is meaningful.

Both fish are good sources of 20:5 (n-3) and 22:6 (n-6), providing about 1 g of n-3 fatty acids in a 100-g daily portion. However, this amount is almost two times lower than anticipated based on the values in Exler (1987). Since the therapeutic value of n-3 fatty acids are thought to he dose-related (Harris et al., 1990; Sanders and Roshana, [983), maximum effect would be produced with larger intakes. A diet designed from information found in the literature would be incorrectly designed if fish such as those: used in our study were actually consumed.

None of the fish contained appreciable quantities of the trans isomer of 18:1 (n-9) but all contained 18:1 (n-7) at greater than 5% relative weight percent. To our knowledge these data have not been reported previously. In view of the fact that it has recently been shown that the trans isomer of 18:1 (n-9) may be hypercholesterolemie (Mensink and Katan, 1990), data such as reported in this study become necessary.

When the data are expressed on a relative weight percent basis, the Dover sole appear to contain more n-3 fatty acids than either the chinook salmon or sablefish: 40.68% versus 21.05% and 20.15%. The muscle in finfish contain about 0.6 g/100 g polar lipid. This accounts for almost all the lipid fraction in low fat fish (Krzynowek el al., 1989). Since polar lipids contain proportionately greater amounts of 20:5 (n-3) and 22:6 (n-3) fatty acids, Dover sole appears to be a better source. However, per serving size. of 100 g, salmon and sablefish provide about I g n-3 fatty acids while Dover sole provides only 0.2 g because its total lipid content is much lower. In a recent metabolic feeding study conducted in our laboratory (Wander and Patton, in press; Gerhard el al., in press), we found that the consumption of 200 g of Dover sole as part of a high fat diet did not change several risk 'factors associated with CVD while the consumption of salmon and sablefish did.

As it becomes dear that each fatty acid may play its own unique biological role (Kestin et' al., 1990; Grundy, 1990), the content of individual fatty acids in the diet needs to be known. This knowledge requires more information about the lipid content of foods. The data contained in this study serve merely as a caution to suggest that one of the most frequently used sources of nutrient composition (Exler, l 987) provides only an estimate of the fat content of fish. More definite assessment will require greater sampling and composite preparation under known conditions (Stansby, 1986). Additionally, the impact of the method of preparation must also be evaluated.

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